Study of a GIS Based Land Use/Cover Change Model in Laos

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Abstract: This is based on the AGENT-LUC model framework. Luangprabang Province has the largest percentage of shifting cultivation area in Laos PDR. The model simulates the spatial and temporal patterns of the shifting cultivation in the study area, using a GIS database while the total area of shifting cultivation is controlled by supply and demand balance of food.The model simulation period is from 1990 to 1999, at a spatial resolution of 500m. The results are evaluated using statistical data and remote sensing images. Through the validation, it is concluded that the trends simulated agrees to that of statistical data and the spatial and temporal patterns are also replicated satisfactorily.
Keywords: Shifting cultivation, GIS, agent, land use/cover, Laos

1. Introduction

1) Background

Shifting cultivation is a sustainable form of agriculture or not, depends on the length of the fallow periods and the status of such land – secondary vegetation or natural forest areas, when farmers start clearing it and put it to cultivating crops. There are two main factors that are influencing the changes in the shifting cultivation system. One, is due to the permeating effect of the money-based economy, which is leading the farmers in the mountainous areas or in areas with limited lowlands to grow such crops and vegetables that are meant for selling in the local markets. On the other hand, with the increasing population, there is extensification of the agricultural areas for increasing food production. This is affecting the Shifting cultivation areas too, leading to reduce fallow periods in the cultivation cycles, which then deters the recovery of the soil fertility. Hence, to increase the cultivation area, we have the dual problem of new forest clearings or use areas with relatively poor soils.

Research and development of quantitative models to process shifting cultivation are still being developed or almost non-existent which use the socio-economic conditions of the villages. Since the conditions under which the shifting cultivation is practiced is different in different areas, it is necessary to analyze these in reference to their spatial condition to understand the processes involved and the spatial impacts on the surrounding forest areas. Also, since most of these areas are in the mountainous regions, there is limited reliable statistical data on the actual condition too. Hence new methods of assessing and monitoring of these areas is needed for getting better estimates of the spatial extent of the shifting cultivation.

2) Objective

The authors have developed an agent based model, which is mainly a micro-scale model to simulate the spatial and temporal patterns of the shifting cultivation in the study area, using a GIS database for managing the inputs and outputs. The aims of this research is (i) to possibly replicate the complicated process of shifting cultivation and to clarify the process of expansion of shifting cultivation area; (ii) to grasp the land use change including shifting cultivation; (iii) to evaluate the reproducibility of the model developed.

3) Characteristics of Study Area

The study area of this research choosen is Luangprabang Province located in the Northern part of Laos and having the most shifting cultivation area in the country. Laos has approximately 70 ethnic groups. They are called Lao Sung, Lao Theung and Lao Lum depending on the altitude of their habitation. Generally Lao Lum are at altitudes less than 400m, Lao Theung at 400-1000m, and Lao Lum at over 1000m. Traditionally, Lao Theung and Lao Sung do shifting cultivation in mountain areas while Lao Lum cultivate paddy field traditionally (Chazee, 1999).

2. Data Use

The model developed here needs a lot of information from various sources that are used as inputs and to derive the rules of the decision-making for the agents of change. Some of the data was readily available and needed only processing it to suit the model needs, while other data was generated from other related information and proxy data available for the study area and period.

3. Development of Model

The model developed in this research is an agent based model which determines the location, area and fallow period of shifting cultivation in each village independently, by considering the food supply-demand conditions, and with links to the wealth of information derived from the village level interviews, available statistical and spatial data. Each village is represented as an independent agent of change in the model.

1) Model Structure

The share of harvested rice area compared with other crops in Luangprabang Province was 83% in 1990 and 68% in 1999. The staple diet of Lao people is glutinous rice and they steam it to eat (State planning Committee, 2000). During the household survey, it was observed that some of them have rice insufficiency and so, it is very important to secure the rice for self-sufficiency and their livelihood is influenced by the rice productivity. So, the authors developed this model focusing on the rice crop.

The overall structure of the model is represented in Figure 1. This model consists of 5 modules, Irrigated and Season Rice Module, Shifting Cultivation Module, Agricultural Income Module, Population/Migration Module, and Land Use Decision Module. The main outputs from the model are the land use map at the end of each year of simulation and the migration/population maps. The various modules are explained in the following sub-sections.

2) Irrigated and Season rice Module

This module determines area and location of irrigated and season rice based on the demand-supply situation, land condition and the potential suitability to grow rice. Since, it is difficult to expand area under irrigation without knowing the accompanying costs for irrigation facilities, it is assumed to follow the statistical trend, which is used as a proxy for the policy and other resource availability. Also, there is a government policy to resettle the upland tribes - Lao Theung and Lao Sung to lowland areas, which will affect the season rice cultivation areas and their extent. So, once again the statistical values are a proxy for the trend in addition to the demand-supply, within the model calculations to identify the increase in paddy land and the rice supply situation.

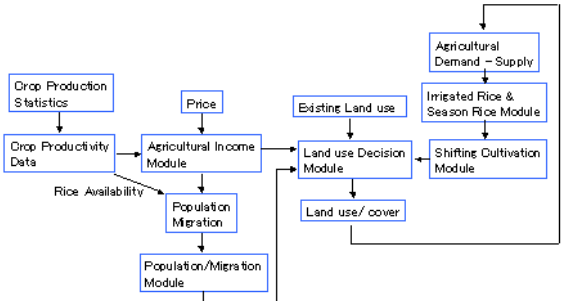

Figure 1. Overview of this model

3) Shifting Cultivation Module

In this module, the area and location of the shifting cultivation fields are determined. Since most of the cultivation depends on the needs of the village population and assuming that no two villages compete for the same region around their villages, the scale at which the decisions are made in this module are at the village level. The agent of change here is the "village" agent.

Within the village boundary, based on its population and consumption patterns, the rice required is calculated. Assuming that the rice demand is satisfied within the village, the upland rice production is calculated as the difference in the total demand and the supply from cultivation in irrigated and season rice fields. Then the module identifies and locates the upland rice field location based on the shifting cultivation cycles and the area needed to produce such quantities at the productivity level of the village. Crops other than rice are mostly grown under shifting cultivation. The supply is calculated from the harvested area and crop productivity in each village, while crop demand is calculated from daily consumption per capita statistics. To satisfy the demand, the area under cultivation may change from year to year.

The area needed for shifting cultivation is the sum of the areas needed under upland rice and crop cultivations. Depending on cultivation cycle and whether the change in the area is negligible or substantial, the cultivation area is either moved only or moves to an expanded field area. Shifting cultivation cycle is calculated as the ratio of the sum of the fallow area, upland rice area and crop area to the sum under upland rice and crop cultivation in a given year.

4) Agricultural Income and Population/Migration Module

In the agricultural income module, the household incomes are calculated based on the production quantity, cost of production, and price. Based on the interview survey information, the use of fertilizers and agricultural machinery is discounted off here. To get a fare idea of the price changes on an annual basis, the inflation rate is also considered here. The fluctuations in the income are averaged over a period three years to smoothen the sudden changes in land use changes, but will drive the change if the fall in income is very large.

Population/Migration module determines the population growth and migratory tendencies of the population. Here the calculations are based on the assumption that people migrate when there is a shortage of food and fall in their incomes. The module also calculates the destination of these migratory populations and may give rise to new village locations or some resettlements of the population.

4. Results and Discussion

Figure 2 shows the graphical comparison of the annual model output and the statistical values of the area under irrigated rice, season rice, upland rice and crop. Irrigated rice can be observed that the two curves are quite close, this is so because this growth trend was external to the model and a given value. This is so, because this growth trend has been used as a proxy for the government policy and the infrastructure available in the year considered.

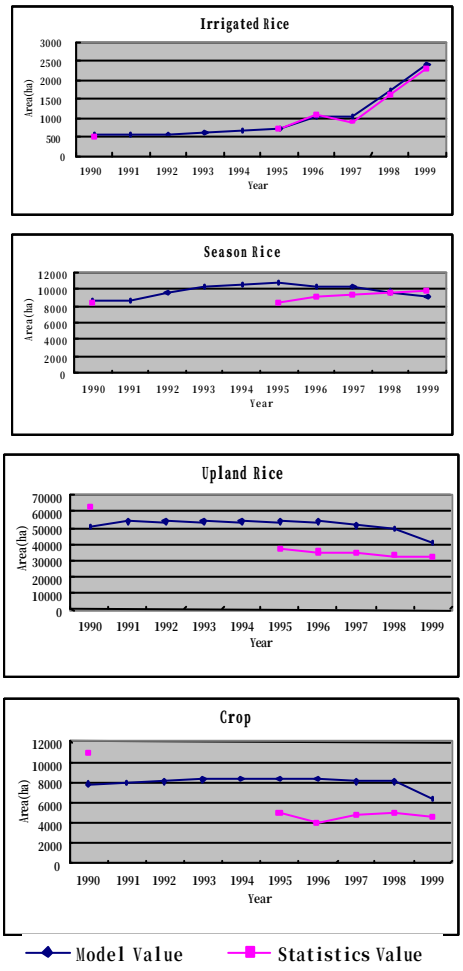

Figure2. Comparison of the model output and the statistical values of the area.

In case of season rice, it can be observed that the statistical value for 1999 is less than the model simulated value. Since there is no data available from statistics for the years of 1991-94, it is difficult to validate the model values during this period. But, for the years from 1990 to 1995, the calculated error is about 10%. The two issues here are – the lack of information in the start years making model tuning difficult; and the need for additional information on labour and technology availability for promotion of new areas under sedentary agriculture of rice.

The model values of upland rice and crop are an overestimate over the statistical values, which may be due to the errors in the statistical values that is available in this area, and the lack of annual values in the start years of the simulation. Also, as we are using the maize crop as a representative for all the crops grown in shifting cultivation area, the model estimate errors could be from the price differential between these crops.

Spatial validation for the shifting cultivation was done with a comparison of the model results with the remote sensing derived outputs (Nagasawa et al., 1998). The general pattern is noticeable, even though the results obtain through the two data sets is not exactly the same because of the difference spatial resolution. But, when the total areas of shifting cultivation within the remote sensing footprint were compared with the model, it was fitted over 80%. This points that the spatial pattern is well replicated in the model framework and it is suspected that the error in area coverage may be due to the actual productivity of the land versus the one calculated in the model.

5. Conclusions

In this paper, the model framework for modelling the spatial and temporal changes in the shifting cultivation has been demonstrated. We find that micro simulation based on the agent approach has its advantages with regard to replicating the village level activity leading to land use changes. But, since there are differences between the statistical and model values, further refinement of the model is required. Also, additional information may need to be collected further refine the decision making rules. As this model is agent based, it is possible to model at larger scales if more detailed information on the household patterns are available, making it a scaleable model to study and analyze impacts of human activity.

6. Refernces

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